

A Review on Retrofit Design and Static Analysis of 3-Axis Gantry System

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Abstract : In the world of high precision fast growing technology Retrofit Design concept for developing low cost high accuracy high precision machineries is required. It is also important to learn the environmental effect of product during the life cycle. In this paper a review of CNC machines, micro milling machines, retrofit design concept, Eco-design concept and design and analysis of CNC parts is presented.

Keywords - Retrofit, Eco-design, micro machines, deflection, finite element analysis

I. INTRODUCTION

In 21st century's need of ultra precision machine required for the micro applications in areas like biomedical, watch maker and jewelers, Information Technology, Telecommunication, Automotive, Aerospace, etc. The cost of the manufacturing process increased due to use of miniature ultra precision machineries which includes intricate and complex parts. In this miniature world the new idea born this named as Retrofit Design for micro machines. The meaning of Retrofit is the replacement of highly cost materials with affordable and easily available parts while development of the precision machineries. Now a days this kind of concept make their impression in fast growing technology which always looks for getting more profit with low production budget.

II. LITERATURE REVIEW

The concept of Retrofit Design has the base of Eco-design. Gunilla Olundh [1] work on the environmental aspects during the product life cycle management. The author introduce the definition of Eco-design as , 'Ecodesign is the design of a product, service or system with the aim of minimizing the overall impact on the environment' .Also they present the four step model of approaches for environmental improvements that are Re-Pair, Re-Fine, Re-Design, Re-Think. Konica Menolta [2] and Xerox [3] encourage the Eco-design concept in their manufacturing process by keeping more than 90% of the parts reused from the recycling process. Endika Gandarias [4] presents the global review on Micromilling Technology. In this review the focus is on the micro machine elements such as machine bed, spindle, guides, driving system and control & monitoring system. The thesis presents a review of the modeling, prediction of temperature distribution while cutting operation by using FEA, micro-structural effect. Kamlakar Rajurkar and Marc Madou [5] gives the status of micro manufacturing process such as microturning, micromilling, micro electrodischarge machining, laser micromachining, near-net shape, and various micro additive processes during the visit of Asian and European Countries.



Fig.1: Micro Lathe [5]

Fig.1 shows the Micro Lathe having dimensions as 32 mm long, 25 mm wide, 30.5 mm high, and weighs only 100 grams which is developed by National Institute of Advanced Industrial Science and Technology (AIST) in Japan. This machine has positioning resolution of 25nm.



(a) Microturning machine (NWU). (b) Three-axis horizontal milling machine (UIUC). (c) Machined components

Fig. 2: Mechanical micromachining in NWU and UIUC. [5]

Fig.2 shows the Mechanical Micro machining developed by Northwestern University (NWU) and University of Illinois at Urbana-Champaign (UIUC).

The micro miniature concept already fixed up their roots in the field of micro electromechanical systems (MEMS) or micro system technology. The new concept of Non-Lithography based micro manufacturing have been developed which includes micro mechanical cutting, micro laser cutting / drilling, micro extrusion, micro embossing, micro stamping and micro injection moulding. [6]. The use of CNC increases the growth of technology in industries. So the new idea of fabrication of low cost CNC was arises which reduce cost and complexity of the CNC system. [7]. Fig.3 shows the fabricated model of the 3 axis CNC machine. This shows the prototype of 3 axis CNC router using Aurduino based control system which gives specifications like low cost, easily operable, easy interface, flexible, low power consumption. This system is designed and analyzed under affordable budget. [7]. One of the essential elements of a CNC machine is a gantry system. The X, Y and Z movements are obtained by these slides.



Fig.3: Fabricated Model of low cost CNC router [7]

The slide length depends upon the required work envelop. The use of Retrofit Design concept by keeping Eco-design as a base it may possible to built an alternative machineries for exiting high precision high cost machineries.

III. DESIGN METHODOLOGY AND ANALYTICAL SOLUTIONS

The most important aspect is to design a structure which gives rigidity and which is responsible for the improvement of the accuracy if the system. Researcher works on the bionic structural design for columns of the gantry system. Gingko root system structure as shown in Fig.4: [8]

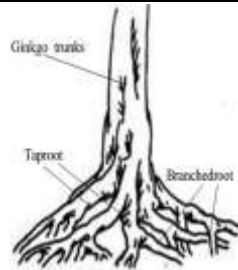


Fig.4: Ginkgo root system structure [8]

From this system the idea of Bionic Design structural system arises. The structure of bionic design as shown in Fig.5:

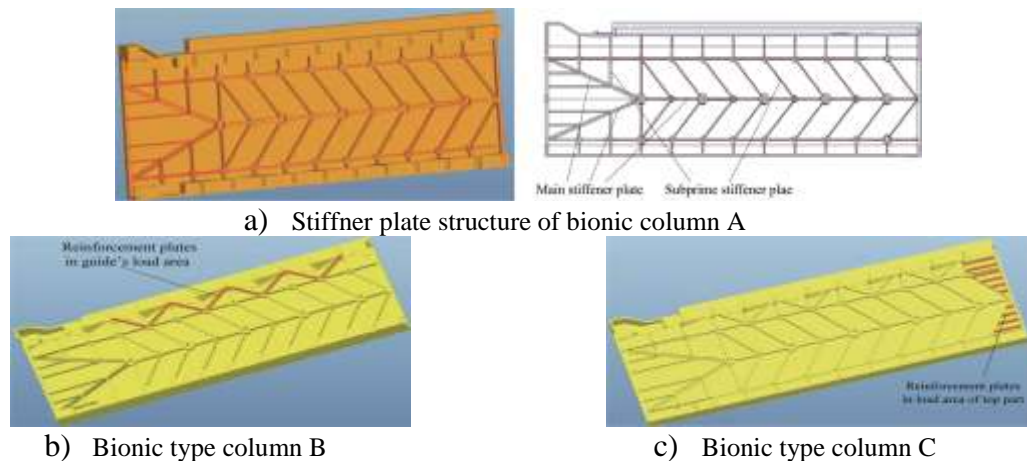


Fig.5: Bionic type Columns [8]

The forces are distributed in stiffener plates which are jointed as a root like structure. The FE analysis results are shown in Fig.6:

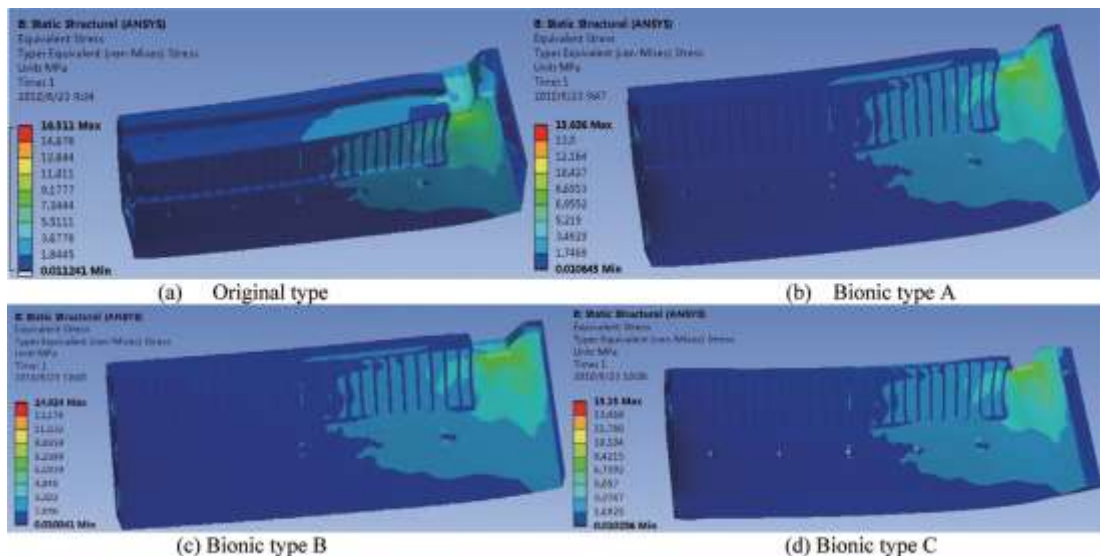


Fig.6: Von mises stresses of columns [8]

From this analysis it is found that bionic type design structure is best solution than the original type structure. The use of bionic structural design reduces mass of the column by 2.74% and 1st five orders natural frequencies are increased by 6.62% on an average. [8]

Micro milling machine is a versatile machine tool in the building of micro factories. S.Thumbkar [9] presents the FE Analysis of positioning slides of Micro Milling Machine. Retrofit concept is used to select the

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components from salvage considering its sustainability in the form of accuracy and repeatability for the development of 3-axis micro milling machine. The performance of the machine depends upon the guide ways used for motion of the slides along X, Y and Z axis. The undesired deflection of slides due to cutting and operating forces affects the performance obtained. To solve this problem detailed analysis of the slides is done by using classical bending equations. The CAD model used for the analysis is shown in Fig.7.

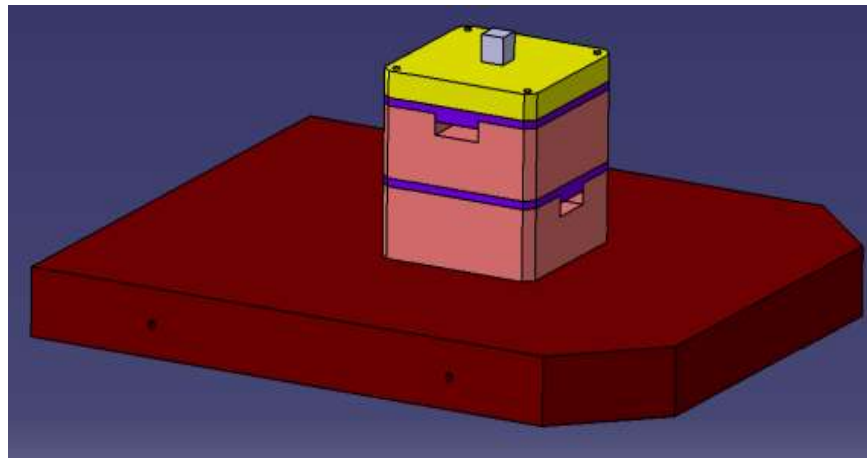


Fig.7 : Slide considered for analysis [9]

Deflection of the cantilever beam is given by the equation,

$$\Delta l = PL^3 / 3EI$$

Where,

P= Cutting force exerted by tool (N)

L= Length of beam (Base plate).

E=Young's modulus

I=Moment of Inertia

For software analysis CAD model is imported in ANSYS software and the forces are applied as shown in Fig.8.

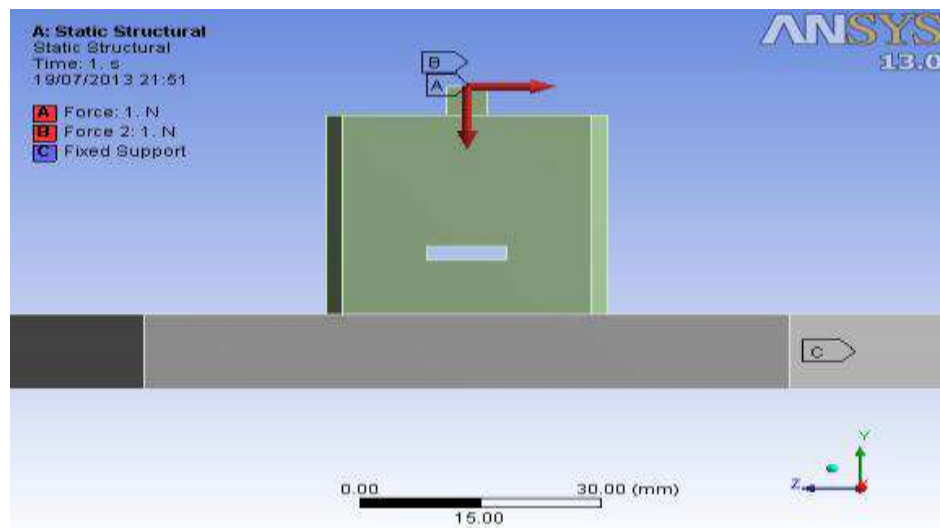


Fig.8 : Force application [9]

After application of the forces the von misses stresses induced and total deformation is calculated as shown in Fig.9.

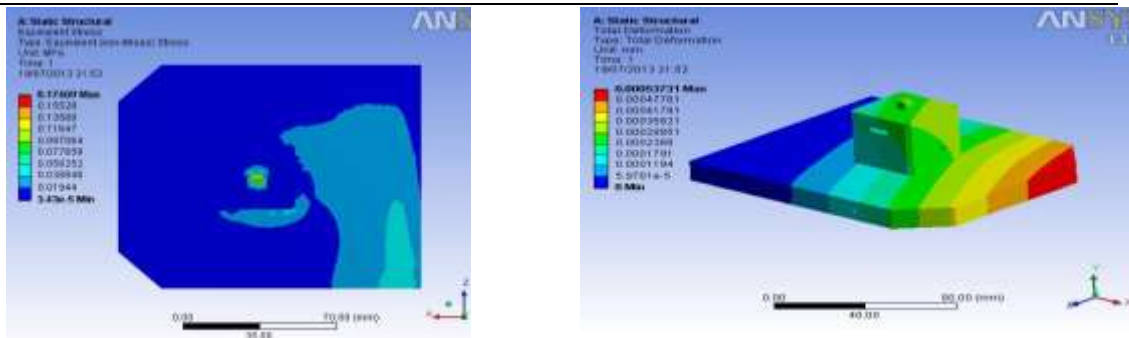


Fig.9: Von misses stresses and Total deformation [9]

The design of the model shows satisfactory by comparing analytical and ANSYS results.

Ahmed A.D. et al [10] work on the improvement on a CNC gantry machine structure design for higher machining speed capability. The CNC gantry milling machine is designed to produce good surface finish. The preliminary model and final design model are shown in Fig.10:



a) Preliminary Design of the gantry system b) Final Modified Gantry Structure
Fig.10: Improvements in model of gantry [10]

Dynamic analysis used to calculate the lowest frequency achieved which is 202.3Hz. After modification the weight of the gantry structure was 627.0kg, each column weighing 191.83kg, the beam 114.3kg and the z-axis part weighs 129.06kg. The entire beam deformation under weight of beam and z-axis part (243.36kg) was analyzed and the results obtained as below in Fig.11:

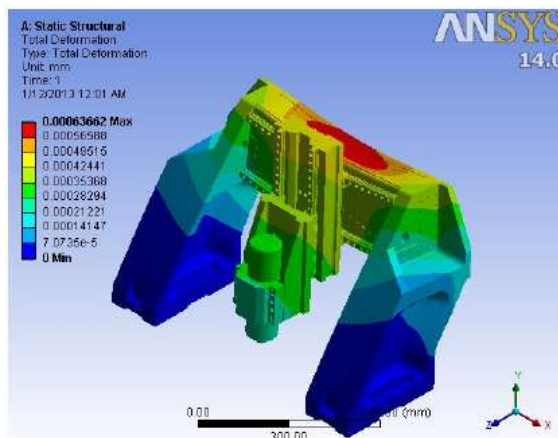


Fig.11: Static structural deformation [10]

Deshmukh B. et al [11] work on retrofit design of 3 axis gantry using components from salvage. The system gives the retrofitting concept which is compatible to a 250 x 250 x 50 mm pulsed laser work station as shown in Fig.12:

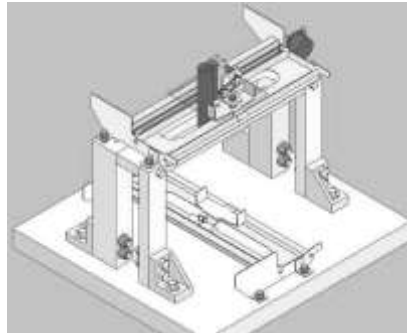


Fig.12: Laser workstation gantry [11]

IV. CONCLUSION

Retrofit Design concept plays important role in design and manufacturing of low cost and high precision micro machineries. For CNC machineries there is a need to design and analyze the gantry system which required for improving the design parameters and accuracy of the machines. To work on Retrofit Design concept, it's a need to study the aspects of Eco-design which helps to learn the environmental impact on the entire product life cycle.

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